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p. 8

FLUID PHASE SEPARATION (FPS) EXPERIMENT FOR FLIGHT ON THE SHUTTLE IN A GET AWAY SPECIAL (GAS) CANISTER: DESIGN AND FABRICATION

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The separation of fluid phases in microgravity environments is of importance to environmental control and life support systems (ECLSS) and materials processing in space. A successful fluid phase separation experiment will demonstrate a proof of concept for the separation technique and add to the knowledge base of material behavior. The phase separation experiment will contain a premixed fluid that will be exposed to a microgravity environment. After the phase separation of the compound has occurred, small samples of each of the species will be taken for analysis on Earth. By correlating the time of separation and the temperature history of the fluid, it will be possible to characterize the process. The phase separation experiment is totally self-contained, with three levels of containment on all fluids, and provides all necessary electrical power and control. The controller regulates the temperature of the fluid and controls data logging and sampling. An astronaut-activated switch will initiate the experiment and an unmaskable interrupt is provided for shutdown. The experiment has been integrated into space available on a manifested Get Away Special (GAS) experiment, CONCAP 2, part of the Consortium for Materials Complex Autonomous Payload (CAP) Program, scheduled for STS 42 in April 1991. This document presents the design and the production of a fluid phase separation experiment for rapid implementation at low cost.

INTRODUCTION

The separation of fluid phases in microgravity is of interest for materials processing and long-duration life support systems in space. On Earth, phase separation occurs due to buoyancy, but this is not the case in the microgravity environment of space. Therefore, materials processing relying on the phase separation of liquid mixtures will not occur in the same way as on Earth. This difference could be used to advantage to develop new materials not presently available on Earth.

Fluid phase separation has direct application to current research concerning new metal alloys produced in microgravity. To optimize the processing method for the alloys, the relationships between the different phases of the metal must be known (i.e., a phase diagram). Microgravity alters the phase diagram. To construct a new phase diagram, the molten metal needs to be analyzed while in space. It has been proposed that a simpler method could use special fluid mixtures to model the molten metals. This has the advantage that the transition temperature of phase separation for most fluids is significantly lower than that of molten metals, so it will be easier to study the fluids in the laboratory and then correlate the data to the metals. The result will be a new space-based phase diagram that can be used to develop stronger, lighter-weight metals.

Another possible application concerns spacecraft thermal control systems. The heat from components, experiments, and people must be dissipated from the spacecraft environment. Present technology utilizes pumped liquid thermal transport systems for heat exchange. The heat dissipation is controlled by the mass flow rate of the system, which is determined by the size of the pump. Large heat dissipation requires large pumps that use a prohibitively large amount of electrical power and add significantly to the weight of the spacecraft. A specialized two-phase (liquid-to-liquid) thermal transport system could be more efficient in accomplishing this task. Therefore, understanding the liquid-liquid phase separation process in space could aid in the design of closed environments, such as the Space Station and the Mars mission.

A detailed understanding of the separation process is essential to the application of the fluid phase separation technology. Preliminary research concerning potential fluid mixtures and their behavior in space is underway. However, the fluid phase separation process is a complex interaction between temperature and microgravity that is not possible to duplicate in an earthbound laboratory. An experiment is needed that will characterize the separation process in space and demonstrate a proof of concept for the fluid phase separation technique. Since this is a high priority project, it would be advantageous to fly the experiment as soon as possible. At the University of Alabama in Huntsville, a fluid phase separation experiment has been designed that satisfies all these requirements.

The experiment will record a complete temperature history of the fluids, along with samples of component species to be analyzed on Earth. The phase separation experiment is totally self-contained, with multiple containment levels for all fluids, and provides all necessary electrical power and control. Furthermore, the fluid phase separation experiment has a unique opportunity to take advantage of space available on a manifested Get Away Special (GAS) Canister, CONCAP 2, which is scheduled for STS 42 in April 1991.

This document presents a summary of the design for the Fluid Phase Separation (FPS) experiment. It includes the description of the process, design of systems, and outline of a construction program.

EXPERIMENTAL PROCESS

A mixture of succinonitrile and cyclohexane is of particular interest. Succinonitrile is a solid at 20°C (room temperature) and has a vaporization temperature of 85°C. This material is highly reactive with most metals except for gold and stainless steel. Plastics and rubber are also reactive, but teflon is not. Cyclohexane is a liquid at room temperature and has a vaporization temperature above 120°C. It is an organic solvent that will dissolve most adhesives. All the materials used to contain and support the fluids must be carefully selected so as not to interact with the liquids to produce erroneous results or jeopardize the saftey of the experiment.

The experiment is a mixture of two fluids that are dormant both before and during launch. The mixture will not need to be heated prior to the experiment start-up since the mixture will contract uniformly upon freezing. Just prior to the second sleep period, during a time of low activity, each of the fluid samples will be heated to a predetermined temperature (less than 90°C) and allowed to stabilize at that temperature for four to six hours. The controller will signal the heaters to shut down and the the system will begin to cool. When the fluid reaches the transition temperature (a function of composition, density, and initial temperature), the phase separation will then begin, accompanied by a release of heat. This will cause the fluid temperature to temporarily stabilize. As phase separation continues, the fluid temperature will once again begin to fall and the sampling mechanism will be activated. The temperature of the fluid will be stabilized and maintained constant, permitting small samples of each of the species to be taken for analysis on Earth. By correlating the time of separation and the temperature history of the fluid, it will be possible to characterize the process. After the sampling is complete, the experiment will be deactivated for the duration of the space shuttle mission.

On Earth, differences in density typically drive the separation process. In microgravity, minimal surface energy will be controlling the separation. It is anticipated that this will produce two spherically shaped volumes containing the different component species. One component will be collected at the center of the fluid container, while the other will be wrapped around the first, positioned at the edge of the container. The fluid phase separation experiment will be used to characterize this process.

DESIGN SUMMARY

The fluid phase separation experiment has a total weight of 11.8 lb and a volume of 1105 in^3, which is within the initial payload constraints imposed by CONCAP 2. This value includes six fluid containers and the support apparatus, the controller, and power supply. The overall dimensions are 14.5 in (width) $\times$ 8.5 in (height) $\times$ 9.75 in (depth from the mounting plate). Volume of an individual fluid sample is 0.22 in^3 and the complete assembly is 0.8 lb. The GAS canister is shown in Fig. 1 with the relative placement of the components within the GAS Can.

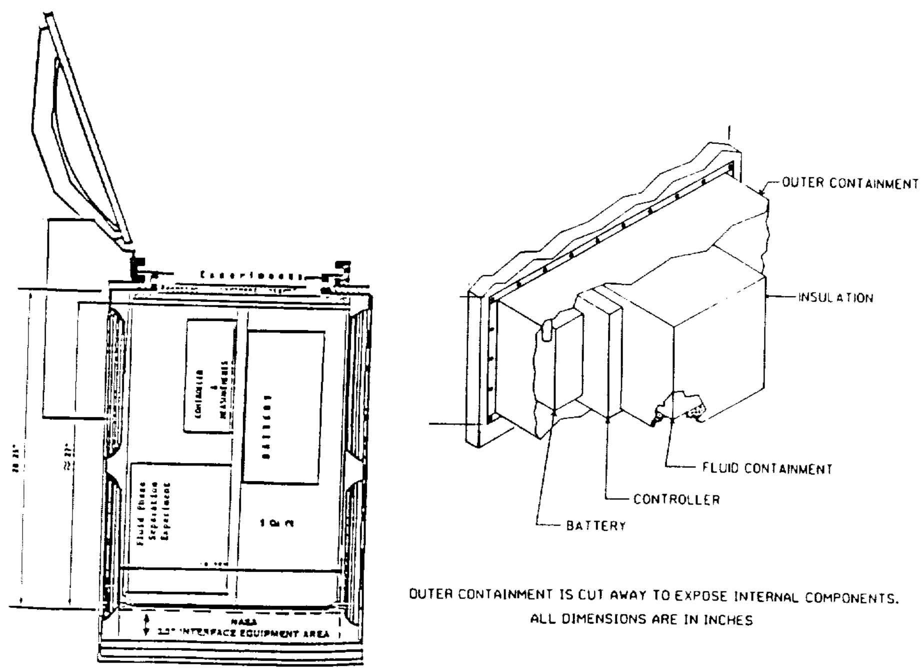

Fig. 1. GAS Canister and Fluid Phase Experiment

STRUCTURAL SYSTEM

The structure will support the experiment and isolate the fluid phase separation experiment from the rest of the GAS Can. The whole experiment will be contained within this shell and will allow the liquid containers and sampling mechanism to be attached to the GAS Can mounting plate.

Several ideas for the shape of the outer shell were considered. The criteria used to evaluate the proposed shape included size of the enclosed volume, minimization of the weight, ease of fabrication, and structural stability. The dimensions of the GAS canister and the allocated space provided by CONCAP 2 set the maximum dimensions. The experiment was to be located in the bottom, on one side of the canister, and have a height of no more than 10 in. Later, the height was further reduced to 8.5 in due to a change in the primary experiment, CONCAP 2.

It was decided that the volume occupied by the fluid phase experiment should be large enough to fully contain six fluid sample containers, a controller, and a battery. Since the experiment had to be completely isolated from the other experiments in the GAS canister, there needed to be a minimum of seams and joints in the outer shell. To maximize structural stability, the shell needed to be self-supporting.

The semicylinder was chosen as the best shape for the outer shell (Fig. 2). The shell will have a length of 14.5 in, a height of 8.5 in, and a depth (measured out from the mounting plate) of 9.25 in. The shell will be formed from 0.031-in, type-304 stainless steel sheet, which is inert to the chemicals used for the fluids. By using thin steel, we can maintain the high strength and minimize the weight. The 304 stainless steel is easy to form and can be welded to increase the strength of the shell and provide containment.

To reduce the weight, there is no backplane on the shell. The containment is maintained by covering the GAS Can mounting plate with a continuous 3-mm-thick teflon sheet. A 0.125-in-thick teflon O-ring gasket is placed between the outer shell and the mounting plate to absorb the displacements induced by thermal and mechanical loads. This will maintain a tight seal and prevent contamination of the other experiments in the GAS Can.

The shell is held to the mounting plate by 22 #10-24 grade 8 socket head bolts with 0.5-in washers. The bolt material is A-286 corrosion-resistant steel with an allowable stress of 20 Ksi. The bolts are spaced at 2 in centers around the 0.75-in flange on the outer shell. Although 22 bolts are not needed to support the outer shell, they are needed to maintain an adequate distributed pressure between the teflon gasket and the mounting plate to ensure a tight seal under launch loads. This bolt configuration produces a worst-case maximum bolt stress of 3000 psi, for a factor of safety of 6, under a 10-g load applied during the launch. The outer shell experiences a maximum stress of 400 psi at launch, which is well below the yield stress of the stainless steel and should prevent even a fatigue failure of the outer shell.

The shell will be penetrated at three points. A D-type electrical connector is located on the bottom of the shell to connect with control cables from the shuttle (located at the bottom of the GAS Can). The connector will have gold-plated pins and a teflon gasket on the interior to prevent corrosion and contamination of the GAS Can. The other two openings are covered with 7-μm teflon filters in a 304 stainless steel housing. The filters are 25 mm in diameter and have a maximum pressure of 100 psi at the inlet, with an allowable pressure difference of 50 psi. This will permit the purging of the fluid phase separation experiment with nitrogen prior to launch. Also, these two ports will permit rapid dissipation of the interior pressure while maintaining containment of the fluid in the event that the GAS Can is depressurized while in space. If this were to occur, the fluid would sublime to a solid and be trapped by the filter while the nitrogen gas could escape, preventing a rupture of the outer shell.

Fig. 2. Outer Shell and Loading Stresses

An analysis of displacements showed that deflections of the large diaphram-like surfaces were acceptable, but a dynamic analysis showed that the fundamental frequency of vibration was too low. To improve the dynamic response of the outer shell, triangular ribs were added to the top, bottom, and side of the shell. These ribs broke up the area that could freely oscillate, and stiffened the surfaces to out-of-plane motion.

FLUID SAMPLING AND SPECIMEN RETRIEVAL SYSTEM

Within the outer shell is the fluid phase separation experiment. The experimental apparatus is composed of three subsystems: the fluid containers, the sampling mechanism, and

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the structural frame (inner shell). Size and weight restrictions determined the maximum number of fluid sampling systems to six.

Many materials were considered for the fluid containers. Due to the unusual corrosive nature of the fluids, stainless steel, gold, and teflon were the only materials that were chemically suitable. A material with a low specific gravity was desired to minimize weight. Furthermore, uniform thermal conductivity was necessary to transfer heat from the external heaters into the fluid. Since the external heaters are to be positioned on the outside of the container, it is essential that the material have a high melting point. Finally, a high tensile strength will be needed to withstand the expected loads during the shuttle flight. All these criteria are met by teflon.

The teflon was machined into the desired geometrical shape. A 0.75-in-diameter spherical fluid cavity is inside a truncated cone with a nominal wall thickness of 0.25 in. A flat octahedron plate passes through the sphere/cone dividing it in two halves. Assembly of the fluid containers is accomplished using a ferrule-type joint for alignment with six bolts to ensure an adequate seal. This will also provide the first level of containment for the fluid. The orientation of the fluid containers is shown in Fig. 3.

Although a spherical shape both inside and out would be optimal for heat flow considerations, the exterior sphere is difficult to produce. Therefore, a cone was used since it can be easily machined and still provides a minimum of exposed surface to conduct and radiate heat away from the fluid. The shape will produce an even heat flow through the teflon container and into the fluid sphere.

Provisions had to be made to fill the spherical cavity of each sample container after assembly. This problem was remedied by designing a special fill port that included a stainless steel tube press fit into the fluid container and sealed at the outside with a removable teflon plug. This permits overfilling of the spherical cavity so that no air pockets are present within the sphere.

The teflon container has a maximum tensile strength of 3000 psi, which is strong enough to withstand the increase in internal pressure created by partial vaporization of the fluid within the cavity (an internal pressure of 100 psi). However, the controller should terminate the heating of the fluid before this pressure is reached.

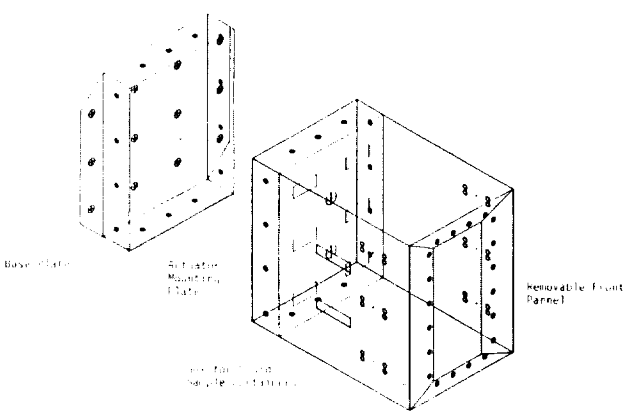


Fig. 3. Inner Shell Showing Two Parts and Mounting Plate

Surrounding the fluid containers is the inner stainless steel shell, which provides the structural support and acts as the second level of containment. The housing will be fabricated from the same material as the outer shell discussed earlier and will also have welded seams. The fluid containers will be mounted within this housing but separated from the stainless steel shell by an insulating phenolic pad to minimize heat transfer away from the fluid spheres. Each of the fluid containers is attached to the inner shell by four #5-40 socket head screws threaded 0.375 in into the teflon. Under the worst loading case at the time of launch, the maximum load (including the preload) is 84 lb per screw. This gives a safety factor of 9 with respect to tear-out, bearing, and shear stresses.

The inner shell is constructed in two parts. A base plate mounts the shell to the GAS cannister with 12 #10-24 grade 8 socket head screws. The A-286 corrosion-resistant steel used in the screws has a 20-Ksi allowable tensile stress, which is four times greater than the maximum stress of 5000 psi that occurs at launch. The base plate has four flanges that are normal to the surface of the plate for attachment of the box containing the fluid spheres.

The box has four sides (open front and back), and is made slightly larger than the tabs of the base plate. The box is then bolted to the tabs on the base plate. Stainless steel nuts were spot welded to the base plate to accept the twelve #5-40 A-286 steel socket head screws. This was done to permit easier assembly of the experiment by allowing access to the front and back of the fluid spheres. To seal the box onto the base plate, a teflon O-ring gasket fits inside the tabs. To completely seal the box, the front panel is attached using twelve #5-40 A-286 steel socket head screws and a teflon O-ring gasket. As before, stainless steel nuts are welded onto the inside edge of the box to accept the screws. This panel permits access to the spheres to fill them prior to launch.

The whole structure of the inner box has a maximum stress of 900 psi, which is well below the yield stress of the stainless steel, and should prevent failure of the inner shell. To stiffen the inner shell and to provide a rigid plate upon which to mount the rotary actuators, a stainless steel plate is welded across the interior of the box. Once all the components are in place, selected areas inside the box are filled with expanded polystyrene foam, which helps to dampen vibration and provides thermal insulation.

The sampling mechanism is composed of two tubes fitted one inside the other (Fig. 4). The exterior tube is rigidly mounted across the inside of the fluid sphere. It has two holes in the wall of the tube positioned such that one is at the center and the other is near the edge. A rotary actuator will rotate the inner tube to align the inner two holes with the outer two and permit diffusion of the fluid species into the inner tube. After sampling is completed, the inner tube will be rotated in a reverse direction to seal the samples within the innermost tube.

The exterior tube is limited to a diameter of approximately 0.050 in to limit the effects of wetting along the tube, which

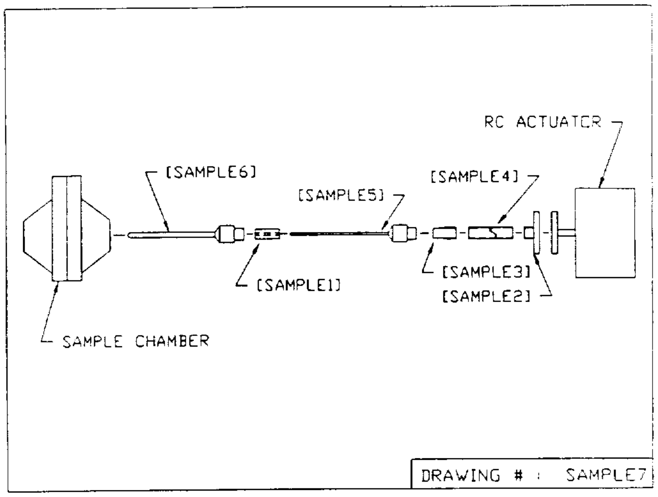


Fig. 4. Fluid Container Assembly

would destroy the concentric sphericity of the two fluids as they separate. To prevent this, the tube has two small disks or fins on it to keep the one fluid from wetting along the whole length of the tube. This will ensure that each component species is sampled.

In order to provide rigidity, precision, and to simplify the design and construction, the sampling tubes are made from stainless steel spinal needles, which are modified as needed. The ends of the needles are closed by a quick touch with a TIG welder. The rotary actuators have a maximum 40° rotation, which limits the size of the holes in the tubes to a diameter of 0.013 in. To make sure that the holes on both tubes are aligned and free of jagged edges that would disrupt the fluid flow into the tube, both holes are simultaneously cut with a file and then the tubes are dipped in nitric acid to remove burrs.

An interference or press fit is used wherever a teflon to stainless steel seal occurs. The outer tube pierces the sampling chamber; the rotary seal between the inner and outer tubes, and the plug in the inner tube are all examples of an interference fit. Adequate pressure is maintained at the seal up to 130°C. This allows for the difference in the thermal expansions of the two materials.

ENVIRONMENTAL CONTROL SYSTEM

The fluid phase separation requires careful control of the fluid temperature during the experiment. Conductive and radiative heat flow will account for the heat transfer within the GAS Can. The design of the environmental control system must compensate for the rapidly changing temperatures of the GAS Can environment while providing enough heat to raise the fluid temperature above the transition temperature so that phase separation can occur.

The problem is not one of steady-state conduction but of time-varying conduction. The orbit (sunlight to darkness every 45 min), periodic turning within orbit, and the attitude of shuttle within orbit (Earth or space viewing) will influence the ambient GAS Can environment. The environment may vary from -100° to 20°C. Therefore, the design of the heaters and the insulation must consider the rate at which heat will be lost from the fluid so that the cooling time is long enough. Likewise, the cooling period must not be too long or the experiment may not be completed within the allotted time.

Initial calculations modeled a fluid heated to 90°C and cooled to 20°C that is surrounded by a cold environment. The fluid is a sphere, at a uniform temperature, which is suddenly immersed in a colder fluid. Surrounding the fluid is a low-density, high-heat-capacity polystyrene insulative layer. As the thickness of the insulation layer increases, the cooling time increases. However, if the ambient environment is too warm, the cooling time becomes prohibitively long. This means that the insulation layer must be designed for the warmer environment and supplemental heating used to stretch the cooling time in colder environments.

A more detailed model was obtained using SINDA (Systems Improved Numerical Differencing Analyzer). This computer program is well-suited to solving lumped parameter representations of physical problems. The model represents the heat flow paths as a conductor/capacitor network.

The experiment components were first broken into smaller elements and assigned a nodal number. The volume and capacitance of each node was calculated. The nodes are then linked to reflect conductive and radiation heat flow paths between all the possible nodes. The final aspect is to assign boundary nodes to represent the properties of space around the GAS canister. This computer model is then converted into executable Fortran code, and run for a predetermined amount of time or until steady state is reached. The end result is a complete temperature history of each node as it cools and/or warms. The temperatures of the fluid were of interest in the cooling phase, and they were dependent upon the temperature chosen for the heat sink (space node). From these tests, the heaters and the layer of insulation were sized and are shown in Fig. 5.

A polystyrene layer, with nominal thickness of 1 in, will be affixed to the exterior of the fluid container housing. Additional insulation can be added within the cylindrical aluminum container and inside the fluid container housing to shield individual fluid containers from the other containers. This will allow customization of individual fluid samples without affecting the overall performance of the experiment.

Sensors will constantly monitor the temperature of the fluid and activate the heaters to keep the liquid from freezing. In orbit, the expected equilibrium GAS Can temperatures are -100°C during space viewing and -10°C during Earth viewing. Due to occasional rotating of the shuttle, the sun may heat the outside of the GAS Can, which may cause the temperature within the GAS Can to rise to 20°C. Although the effects of the extreme cold can be minimized with heaters and insulation, the warming of the GAS Can will be a problem. There is no adequate means at our disposal to cool the experiment if it should get too warm. Because of this, the thermal heating design was determined for the worst-case temperatures of -100°C and it is assumed that the insulation provided will prevent the experiment from warming too much.

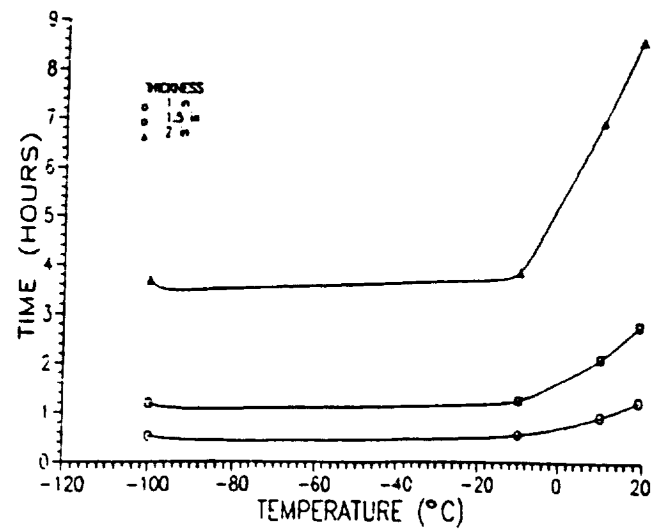


Fig. 5. Thermal Analysis of Cooling Time

Once the experiment begins, the fluid will be heated to a maximum temperature of 90°C over a 1-hr period and then maintained at that temperature for 5 hr. This will require 81 mW/hr or 486 mW total. The fluid will also need to be cooled slowly, so intermittent heating may be required during cooling. Once sampling of the two fluid components begins, the fluid temperature will be stabilized for an additional hour. This heating load is used to determine the size and number of heaters required.

The heat flow for a single fluid container is 81 mW/hr over a 6-hr period. Because there is some thermal lag in transferring the load, and the heaters should not be in continuous operation, the heaters had to have a greater output than the heating load required. It was determined that the heaters should operate only one-third of the time, which requires 243 mW/hr. With six heaters chosen, the output from a single heater must be 40.5 mW/hr. Given that the voltage available from the battery is 6 V, the resistance of an individual heater was calculated to be 0.88 ohms. These requirements can be met by Thermofoil heaters, each having a diameter of 0.5 in, with an effective area of 0.15 sq in.

For control and safety, each heater will have a resistance thermometer laminated within it. The resistance thermometers (RTDs) increase resistance with temperature, and are considered to be accurate and stable sensing devices. The RTD chosen will have either platinum, nickel, copper, or nickel-iron elements.

Temperature sensors will also be needed to monitor the temperature of the sample, as well as the temperature of the battery. They must have an output range from 0-10 V. For the sphere, it will be necessary to have a coated sensor that will resist any type of reaction with the fluid. It must have a temperature range at least from -50° to 150°C. A teflon-coated thermocouple with a length of 0.05 in and a time constant of 1 sec has been selected.

CONTROLLER

The controller executes three primary functions. Function one provides active temperature control of six fluid samples during the experiment cycle. In addition, the temperature of the experiment battery pack will be regulated to maintain optimum battery output throughout the experiment cycle. Function two is the independent timing and control of each of the sample actuators once the phase transition is reached. Function three is the data logging in nonvolatile memory of experiment temperatures for the duration of the experiment's operation. Finally, the controller will monitor safety and control power for the experiment.

The control and data logging requirements for the Fluid Phase Separation Experiment are relatively simple. The requirements fall into four catagories. These catagories constitute the logical division of work for the controller.

Category one is data storage. The nonvolatile electrically erasable and programmable memory (EEPROM) requirements are driven by the number of temperatures stored multiplied by the sample rate, multiplied by the experiment total operating time. A three-day experiment cycle time will generate 30,240 bytes that need to be stored.

Category two is active temperature control. The active control for temperature requires 13 separate temperature inputs, 2 each from each of the 6 fluid specimens plus 1 from the battery. In addition, there are seven temperature control outputs, one for each of the six experiments plus one output for the battery.

Category three is the control of the experiment actuators. There are six one-bit control outputs for the actuation of the experiment sample mechanisms. The timing for the sample mechanisms will be controlled by the temperature inputs from the experiments themselves. A minimum time delay between sample actuation will be used to prevent overloading of the batteries.

Category four covers the general control requirements. This includes the input from the GCD switch actuated by an astronaut to begin and end the experiment. If there is an indication that the battery charge is low (voltage is less than 4.75 V for an extended period), a nonmaskable interrupt will be sent to the controller to shut itself off. This is done for safety since this is the minimum reliable operating voltage for TTL digital logic. Also, a software timer will be monitored by the processor to indicate that the controller is operating the experiment properly. If the experiment does not seem to be progressing (the fluid is not cooling, etc.), another nonmaskable interrupt will be sent to shut off that portion of the experiment. Furthermore, if any of the heaters should fail in the "on" position, the controller would turn itself off to prevent thermal runaway.

To permit speed in construction and ensure certification for flight, the controller will be a modification of NSC 800 controller from the GAS Explorer Program. To test the logical sections and permit integration of the experiment and controller, simulated mission tests will be performed at the University of Alabama in Huntsville.

POWER SUPPLY

A power supply is needed to provide power to various systems in the experiment: sample actuators, fluid heaters, battery heater, data acquisition and storage, and the experiment controller. Collectively, these systems require 3.2 amphours for a 60-hr experiment duration. A 6-V, 5-amphour Gates lead-acid monobloc battery, 5.47 in long, 2.11 in wide, and 3.02 in high will provide the necessary electrical power. The battery weighs 2.43 lb, is self-contained in a flame-retardant material and is flight qualified.

SAFETY

Safety has been of primary concern throughout the design process for the experiment. The potential hazards concerning possible collision, corrosion, explosion, and fire were identified. Each was carefully examined and a detailed description of the hazard, hazard causes, and hazard controls are presented. All the safety requirements are referenced from NSTS 1700.7B, "Safety Policy and Requirements for Payloads Using the Space Transportation System." See Fig. 6 for a condensed description of identified hazards and means to deal with them.

Collision is of paramount concern for any experiment on board the space shuttle. Because of structural failure, damage could occur to surrounding experiments or to the shuttle itself. The result could be a loss of control or even the ability of the shuttle to stay in orbit. The ultimate hazard would be penetration of the crew compartment, placing the safety of the astronauts in jeopardy. To prevent these hazards from occurring, a factor of safety of 1.4 was applied to all structural design. Furthermore, close inspection of all assemblies for quality of materials and workmanship will reduce the potential for material failure. The applicable NASA safety requirements concerning collision (206, 208.1, 208.2, and 208.3) have been met.

Damage of the fluid containment vessels caused by sudden expansion of the sample fluid, collision, or a fire could result in the release of some corrosive material. If the fluid comes in contact with metal, the reaction may weaken the metal and cause the component to fail. To prevent this hazard, the experiment is self-contained with three levels of containment surrounding the experimental fluid. This containment will protect the surrounding experiments by minimizing the spread of shrapnel and corrosive material if a structural failure occurs. These measures fulfill the safety regulations concerning corrosion (206 and 209.1).

Overheating of the battery due to heater runaway, polarity reversal, or short circuit could cause the battery to explode. The battery explosion could spread corrosive material and shrapnel throughout the GAS Can. This is prevented by using a sealed, flight-qualified battery along with a bus board to prevent short circuits. Finally, a pure nitrogen environment around the experiment will deprive a fire of the oxygen necessary to burn. Nonflammable elements will be used near

GAS PAYLOAD SAFETY MATRIX

PAYLOAD: G - CONCAP 2-Fluid Phase | PAYLOAD ORGANIZATION: | DATE: 4 DEC 89 | PAGE:

SUBSYSTEM \ HAZARD GROUP	COLLISION	CONTAMINATION	CORROSION	ELECTRICAL SHOCK	EXPLOSION	FIRE	TEMPERATURE EXTREMES	RADIATION
BIOMEDICAL								
RADIATION								
STRUCTURES	X							
ELECTRICAL					X	X		
ENVIRONMENTAL CONTROL								
HUMAN FACTORS								
HYDRAULICS								
MATERIALS			X					
MECHANICAL								
OPTICAL								
PRESSURE SYSTEMS								
PYROTECHNICS								

GAS HAZARD LIST

PAYLOAD: CONCAP 2-Fluid Phase Sep. Exp. | SUBSYSTEM: MULTIPLE, AS LISTED | DATE: 4 DEC 89

HAZARD GROUP	HAZARD TITLE	APPLICABLE SAFETY REQUIREMENT
COLLISION G - F1	STRUCTURES, MECHANICAL Failure of support structures.	NSTS 1700.7B 206- 208.1 208.2-208.3
CONTAMINATION CORROSION G- F2	MATERIALS Release of contaminating or corrosive materials	206- 209.1
EXPLOSION G- F3	ELECTRICAL Rupture of Battery	206- 213.2
FIRE, TEMPERATURE EXTREMES G- F4	ELECTRICAL Thermal Runaway	206 213.1 213.2

Fig. 6. NASA Safety Regulations and Identified Hazards

connections and all wiring and heaters will be properly inspected. The design is in line with the NASA safety regulations for explosion and fire (206, 213.1, and 213.2).

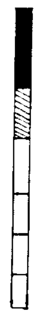
PROJECT MANAGEMENT

The design has emphasized the use of prefabricated components whenever possible to quicken the procurement and assembly of the experiment. The delivery of the battery will be set for August so that the battery is not over six months old at the time of launch. The acquisition of the controller is paramount to assembly of the experiment. Adequate time is needed to modify and test the controller.

The project was designed and assembled by engineering students at the University of Alabama in Huntsville. The fall 1989 Senior Student Design class (ME 465) was the nucleus of the design team. The students were responsible for generating all the necessary design documentation. They will also serve as the transition to the construction phase of the experiment. Construction has begun, with anticipated completion by August 1990. The current work is done by students enrolled in a "Special Topics Class: Advanced Space Systems Design."

The planned schedule for the construction of the fluid phase separation experiment is a fast-paced program to permit complete integration of the experiment into CONCAP 2. The development of the phase separation experiment must meet the existing time schedule for CONCAP 2. In the event that the phase separation experiment fails to meet any of the established requirements, it will be divorced from the CONCAP 2 project.

Figure 7 shows the revised time schedule for the phase separation experiment. It is anticipated that CONCAP 2 will fly on the GAS Bridge on STS 42, scheduled for April 1990.



- **Optimized design for the FPS Experiment (began preliminary design September, 1989 and finished design May, 1990)**
- **Use fast track method for fabrication of flight hardware (anticipate completion by July, 1990)**
- **Begin testing and qualifying, summer of 1990**
- **Integration of experiment into GAS can by Sepetember, 1990**
- **Delivery to NASA in November, 1990**
- **Fly on STS-42 in April, 1991**

Fig. 7. Time Schedule for Project

CONCLUSION

The fluid phase separation experiment will characterize the liquid-liquid phase separation process in a microgravity environment. The experiment allows six samples of fluid to be monitored for three days while in orbit. The system will record temperature data and obtain samples of the component species for analysis on Earth. The data will be analyzed to produce a phase relationship or phase diagram for the fluid mixture. Ultimately, it will add to the knowledge base of material processing and provide information for the design of long-duration life support systems.

The current status of the project is that construction and assembly are underway. It is anticipated that the experiment will be ready for integration into CONCAP 2 by July, and therefore has an excellent chance of flying onboard the shuttle in April 1990.